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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 334

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER December 28, 1915

DIRECTIONS FOR BLUEBERRY CULTURE, 1916.[1]

By FREDERICK V. COVILLE, *Botanist.*

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SPECIAL REQUIREMENTS.

Success in blueberry culture rests especially on the recognition of two peculiarities in the nutrition of these plants: (1) Their requirement of an acid soil; (2) their possession of a root fungus that appears to have the beneficial function of supplying them with nitrogen.[2]

If blueberries are planted in a soil with an alkaline or neutral reaction, such as the ordinary rich garden or fertile field, it is useless to expect their successful growth. In such a situation they become feeble and finally die. Blueberries require an acid soil, and they thrive best in that particular type of acid soil which consists of a mixture of sand and peat. (See Pl. I.)

Good aeration of the soil is another essential. It is commonly but erroneously supposed that the swamp blueberry (*Vaccinium corymbosum*), the species chiefly desirable for cultivation, grows best in a permanently wet soil. It is to be observed, however, that the wild plants of the swamps occupy situations which, though perhaps submerged in winter and spring, are exposed to the air during the root-

[1] Revised by the author from the original paper of 1913, entitled "Directions for Blueberry Culture," which was published, without illustrations, as pages 3 to 11 of Circular 122, Bureau of Plant Industry, and was also separately printed.

[2] For a full discussion of the principles of blueberry culture, including the soil requirements and peculiarities of nutrition of the blueberry plant and the details of the growing of seedlings, consult "Experiments in Blueberry Culture," Bulletin 193, Bureau of Plant Industry, 1910, or the corrected reprint of 1911. Although the edition of this bulletin was long since exhausted at the Department of Agriculture, copies may be obtained from the Superintendent of Documents, Government Printing Office, for 25 cents each.

forming period of summer and autumn or, when growing in permanently submerged places, they build up a hummock or a cushion of moss which rises above the summer water level and within which the feeding roots of the bush are closely interlaced. In actual culture, moreover, it has been found that the swamp blueberry does not thrive in a permanently wet or soggy soil.

Although some species of Vaccinium, such as the common low-bush blueberry of the northeastern United States, *V. angustifolium* (called V. *pennsylvanicum* by some authors), grow and fruit abundantly in sandy uplands that are subject to drought, the swamp blueberry grows best in soils naturally or artificially supplied with adequate moisture.

These, then, are the three fundamental requirements of successful blueberry culture: (1) An acid soil, especially one composed of peat and sand; (2) good drainage and thorough aeration of the surface soil; and (3) permanent but moderate soil moisture. Under such conditions the beneficial root fungus which is believed to be essential to the nutrition of the plant need give the cultivator no concern, for even if the necessary fungus were wholly lacking in the soil of the new plantation each healthy bush set out in it would bring its own supply of soil-inoculation material.

Next in importance to soil conditions is a convenient location with reference to a good market. The berries should reach their destination without delay, preferably early in the morning following the day of picking. To secure the best prices they should also reach the market about the beginning of the main wild-blueberry season. A situation to the south of the great areas of wild blueberries in northern New England, Canada, and northern Michigan is therefore desirable. One of the most promising districts for blueberry culture is the cranberry region of New Jersey, for there an ideal soil occurs in conjunction with an early maturing season and excellent shipping facilities to the markets of Philadelphia, New York, and Boston.

Situations liable to late spring freezes, such as the bottoms of valleys, should be avoided, for while the blueberry plant itself is seldom injured by freezing, its crop of fruit is often destroyed in this way.

In seasons in which the wild crop of upland blueberries has been destroyed by late spring freezes, it has been observed that in or around bodies of water, such as cranberry reservoirs or cranberry bogs temporarily flooded to prevent frost or insect injury, the wild bushes often produce normal crops of blueberries. It may be found that provisions for flooding blueberry plantations will save a crop often enough to warrant the installation of flooding equipment. In locating a blueberry plantation, therefore, it would be well to choose a situation that could be flooded, if flooding proved later to be commercially advantageous.

IMPORTANCE OF SUPERIOR VARIETIES.

In the southern United States and in the Middle West blueberries are not ordinarily distinguished from huckleberries, but in New England the distinction is very clearly drawn. The name huckleberry is there restricted to plants of the genus Gaylussacia, the berries of which contain 10 large seeds with bony coverings like minute peach pits, which crackle between the teeth. The name blueberry is applied in New England to the various species of the genus Vaccinium, in which the seeds, though numerous, are so small that they are not noticeable when the berries are eaten. It is probable that the comparatively low estimation in which this fruit is held in the South is largely due to the lack of a distinctive popular name and the consequent confusion of the delicious small-seeded southern Vacciniums with the coarse large-seeded Gaylussacias. It is the culture of the small-seeded blueberries only, as distinguished from the large-seeded huckleberries, that is here advocated.

From the market standpoint, the features of superiority in a blueberry are sweetness and excellence of flavor; large size; light-blue color, due to the presence of a dense bloom over the dark-purple or almost black skin; "dryness," or freedom from superficial moisture, especially the fermenting juice of broken berries; and plumpness, that is, freedom from the withered or wrinkled appearance that the berries begin to acquire several days after picking. Large berries cost less to pick than small ones and bring a higher price. A berry eleven-sixteenths of an inch in diameter has already been produced under field culture, and others of still larger size are to be expected.

Although blueberry plantations may be formed by the transplanting of unselected wild bushes or by the growing of chance seedlings, neither of these courses is advocated, because neither would result in the production of fruit of an especially superior quality. Seedling plants, even from the largest berried wild parents, produce small berries as often as large ones. Until nurserymen are prepared to furnish plants asexually propagated from superior stocks, the cultivator should begin by the transplanting of the best wild bushes, selected when in fruit for the size, color, flavor, and earliness of the berry and the vigor and productiveness of the bush. These he should propagate by layering and by cuttings until his plantation is completed. Through a combination of these methods, a valuable old plant can be multiplied by several hundred at one propagation, the fruit of the progeny retaining all the characteristics of the parent.

PROPAGATION.

While grafting and especially budding are useful in experimental work, neither method is suitable for commercial plantations, because blueberry bushes are continually sending up new and undesirable shoots from the stock. The best season for budding for experimental

purposes is from the middle of July to the end of August. The ordinary method of shield budding, with dry and unwaxed raffia wrapping, has proved the most successful of all the methods tried. The best wood on which to bud is the lower portion of vigorous basal shoots of the season, especially those from plants that were cut to the stump in the preceding winter. On such shoots the bark can be lifted with ease much later in the season than on older stems. Special care must be taken that the raffia wrapping does not become wet and fermentation ensue between the raw surfaces of bud and stock, in the first three weeks. By that time, in normal cases, the bud wood has united with the stock, and if the budded stem has increased in diameter sufficiently to cause pronounced choking by the raffia the wrapping should be removed. If choking does not occur the wrapping may be allowed to remain until spring, when the stem is cut off above the still dormant bud. In greenhouse experiments, a growth of over 8 feet has been secured from an inserted bud in its first growing season, all other growth from the stock having been promptly rubbed off as soon as it started.

STUMPING.

The easiest way to propagate the swamp blueberry is by a special process of layering named "stumping." The directions are as follows:

1. In late fall, winter, or spring, preferably in early spring before the buds have begun to push, cut off at the surface of the ground either the whole of the plant or as many of the stems as it is desired to devote to this method of propagation. The stems that are cut off are discarded, or they may be used for cuttings, as described under "Tubering" or "Winter cuttings."

2. Cover the stumps to the depth of 2 to 3 inches with a mixture of clean sand and sifted peat, 2 to 4 parts of sand to 1 of peat, by bulk. A rough box or frame may be built on the ground to keep the sand bed in place.

3. Care must be taken that the sand bed be not allowed to become dry except at the surface during the summer.

4. The new growth from the stumps, which without the sand would consist of stems merely, is transformed in working its way through the sand bed into scaly, erect, or nearly erect rootstocks which, on reaching the surface of the sand, continue their development into leafy shoots. (See Pl. II.) Although roots are formed only sparingly on the covered bases of stems, they develop abundantly during spring and early summer on these artificially produced rootstocks, and by the end of autumn all the shoots should be well rooted at the base. They should remain in place in the sand bed till late winter or early spring, undisturbed and exposed to outdoor freezing temperatures; but the sand should be mulched with leaves, preferably those of red oaks.

5. Early in the following spring, before the buds have begun to push, open the bed and sever each rooted shoot carefully from the stump. Discard the upper portion of the shoot, making the cut at such a point as to leave on the basal portion about three buds above the former level of the sand bed. If the cut at the basal end of the rooted shoot is not smooth or the wood is cracked, recut the surface with a sharp thin-bladed knife. The discarded upper portion of the shoot may be used for winter cuttings, as described on pages 8 to 11.

6. Set the rooted shoots in a coldframe or a cool greenhouse in clean earthenware pots of suitable size, ordinarily 3-inch pots, in a soil mixture consisting of two parts, by bulk, of rotted upland peat and one part of sand.

7. Cover the frame with muslin or other white shade suspended above the glass, giving the plants plenty of light but no direct sunlight, and for the first two or three months keep the temperature at not to exceed 65° F. if practicable. When subjected to high temperatures the newly cut shoots are liable to die and rot from the base upward. The outer surface of the pots should never be allowed to become dry. The desired condition may be assured by bedding, or "plunging," the pots in moist sand up to the rim.

8. Watering should be as infrequent as practicable, only sufficient to keep the soil moist but well aerated.

9. The frame should receive ventilation, but not enough to cause the new twigs to droop. These are most susceptible to overventilation and to overheating when they have nearly completed their growth. (See Pl. III.)

10. After the new twigs have stopped growing and their wood becomes hard new root growth takes place. Then secondary twig growth follows, either from the apex of the new twigs or from another bud lower down on the old wood of the original rooted shoot. Until this secondary twig growth takes place the life of the plant is not assured.

11. Those plants that make sufficient growth to require repotting during the first summer should be set in clean pots of 2 inches larger diameter in a standard blueberry-soil mixture.

SOIL MIXTURE FOR BLUEBERRIES.

A very successful potting mixture or nursery-bed mixture for blueberry plants consists of one part of clean or washed sand, nine parts of rotted upland peat, either chopped or rubbed through a sieve, and three parts of clean, broken crocks, that is, pieces of ordinary unglazed, porous, earthenware flower pots. No loam, and especially no lime, should be used. Manure is not necessary, and in the present state of our knowledge may be regarded as dangerous, although in small quantities it serves to stimulate the plants, at least temporarily. The danger from manure apparently lies in its tendency to injure the beneficial root fungus of the blueberry plant.

The use of broken crocks in the potting mixture is based on the fact that the rootlets seek them and form around them the same kind of mats that they form at the wall of the pot, thus increasing the effective root surface and the vigor of growth. If crocks are not available, the soil mixture should consist of 2 to 4 parts of peat to 1 part of sand.

The peat most successfully used for potting blueberry plants is an upland peat procured in kalmia, or laurel, thickets. In a sandy soil in which the leaves of these bushes and of the oak trees with which they usually grow have accumulated and rotted for many years, untouched by fire, a mass of rich leaf peat is formed, interlaced by the superficial rootlets of the oak and laurel into tough mats or turfs, commonly 2 to 4 inches in thickness. These turfs, ripped from the ground and rotted from two to six months in a moist but well-aerated stack, make an ideal blueberry peat. A good substitute is found in similar turfs formed in sandy oak woods having an underbrush of ericaceous plants other than laurel. The turfs of low-bush blue-

berries serve the same purpose admirably. Oak leaves raked, stacked, and rotted for about 18 months without lime or manure are also good. The leaves of some trees, such as maples, rot so rapidly that within a year they may have passed from the acid condition necessary for the formation of good peat to the alkaline stage of decomposition, which is fatal to blueberry plants. Even oak leaves rotted for several years become alkaline if they are protected from the addition of new leaves bearing fresh charges of acidity.[1] The much decomposed peat in the submerged lower layers of deep bogs, such as is used for fuel in Europe, is not suitable for blueberry-soil mixtures.

TUBERING.

By ordinary methods, cuttings of the swamp blueberry have been rooted only in occasional instances. Successful special methods, however, have now been devised for these plants. Wild stocks of the swamp blueberry vary greatly in their response to propagation by a particular method, and it is likely to prove true that one variety of cultivated blueberry can best be propagated by one of the methods here described, others by another. The most novel of the methods devised, but the one easiest of operation, is that of tubering. This method involves the same principle as that employed in stumping, namely, the forcing of new shoots in such a manner that their basal portions are morphologically scaly rootstocks, with a strong rooting tendency. The directions for tubering as applied to the swamp blueberry are as follows:

1. Make stem cuttings from outdoor plants between midwinter and early spring, before the buds have begun to make their spring growth, and preferably on a warm day when the twigs are not frozen. A still better plan is to make the cuttings in autumn after the leaves have fallen, and store them for about two months in moist sphagnum moss on ice at a temperature just above freezing.

2. The cuttings are to be made from vigorous plants grown in well-lighted situations and with stems therefore well stored with starch. Use unbranched portions of the old and hardened branches and stems, about a quarter of an inch to an inch, or even more, in diameter. From 3 to 4 inches is a suitable and convenient length. Make the cuts with pruning shears or a fine-toothed saw and remove the bruised wood at the cut ends with a sharp knife. Be careful not to injure the bark or split or strain the wood.

3. Lay the cuttings horizontally in a shallow box or other cutting bed of pure clean sand and cover them to the depth of about half an inch. Moisten the sand well with rain water, bog water, or other pure water (free from lime) from a sprinkling pot, and see that the sand is closely and firmly packed about the cuttings. Cover the box or cutting bed with a pane or panes of glass, the top of the box being flat, so that the glass fits it rather snugly. The box should be so prepared that any surplus water in the sand will drain away beneath through holes in the bottom covered with clean broken crocks and sphagnum moss.

[1] For a fuller discussion of the conditions under which leaves decompose into leaf peat as distinguished from leaf mold, and the fundamentally different effect of the two on the growth of plants, consult "The Formation of Leafmold," Smithsonian Report for 1913, pp. 333 to 343 (also separately printed).

4. Keep the box at a temperature of 55° to 65° F., or as near those limits as practicable. A temperature of 70° or over is likely to ruin the cuttings.

5. In order to avoid excessive temperatures, do not allow direct sunlight upon the glass, either keeping the box by north light or keeping it shaded, as by a white cloth or paper cover suspended several inches above the glass, or in a shaded greenhouse.

6. Keep the air inside the box saturated with moisture. This condition will be evidenced by the condensation of the moisture on the under side of the glass during the cooler part of the day or whenever a cold wind blows against the glass.

7. Watering should be as infrequent as practicable, only sufficient to keep the sand moist but well aerated and the atmosphere in the box saturated. If the glass fits tightly, a second watering may not be needed for several weeks.

8. Within a few weeks new growth will begin to appear above the sand. (See Pl. IV, fig. 1.) When the shoots have reached a length proportionate to their vigor, commonly 1 to 3 inches, their further growth is self-terminated by the death of the tip. After the leaves have reached their full size and acquired the dark-green color of maturity the time has come for the development of roots.

9. When the first shoot has reached this rooting stage a half-inch layer of finely sifted rotted peat, 2 parts, and clean sand, 1 part, should be placed on the surface of the cutting bed and moistened well with water. A time-saving and perhaps desirable modification of this treatment is to use this mixture of peat and sand as the original covering of the cuttings, described in paragraph 3.

10. The new growth, which if it had originated above the sand would be like an ordinary shoot, was transformed in working its way through the sand and became a scaly, erect rootstock, which on reaching the surface of the sand continued its development into a leafy shoot. During the spring and early summer, roots form in abundance on the lower or rootstock portion of these shoots. (See Pl. IV, fig. 2.)

11. After a shoot is well rooted it commonly, though not invariably, makes secondary twig growth the same season, usually from a bud in the axil of the uppermost leaf. If the rooting of the shoot has not already been ascertained by direct examination, the making of such secondary growth is good evidence that rooting has actually taken place.

12. When a shoot is well rooted, with roots 1 to 2 inches in length, it is ready to be potted. (See Pl. V.) If the shoot has not already disconnected itself from the dead cutting, it should be carefully severed with a sharp knife. In the process of tubering, the behavior of the cuttings is essentially identical with that of real tubers, like those of the potato. The original cutting dies, but the sprouts that arose from it root at the base and form independent plants.

13. The rooted shoots should be potted in clean 2-inch earthenware pots in the standard blueberry-soil mixture already described. (See Pl. VI.)

14. The pots should be bedded in moist sand up to the rim in a glass-covered frame or box, well lighted but protected from direct sunlight, and slightly ventilated but with a saturated or nearly saturated atmosphere.

15. In order to secure rapid growth, the rooted plants should be gradually accustomed to a well-ventilated atmosphere and then to half sunlight, this adjustment extending over a period of about three to four weeks.

16. If preferred, the rooted shoots may remain in the original cutting bed until the following spring, the cutting bed being exposed during the winter to freezing temperatures, but mulched with oak leaves, and the plants may then be transferred, with their whole root mat intact, to a peat and sand nursery bed at a spacing of about a foot each way.

Where propagating is to be done on a sufficiently large scale, outdoor coldframes may be used instead of cutting boxes. Miss Elizabeth C. White, of New Lisbon, N. J., who has brought together the best existing collection of selected wild-blueberry stocks, has been propagating them with much success in muslin-shaded coldframes by the method of tubering, and she has much simplified the handling of the cuttings, both before and after rooting. The cuttings are made in the late fall, packed in boxes in loose, moist, clean sphagnum moss, and stored during the winter in a cool cranberry house at a temperature of about 40° F. As soon as the frost is out of the ground beds of clean sand are laid down in the coldframes and the cuttings are pressed into the sand until the upper side is level with the surface. The whole is then covered with an inch layer of sifted peat (about 2 parts) and sand (1 part). The frames are completely shaded by muslin on a framework about 7 feet above the ground (Pl. VII), and ventilation is not begun until most of the shoots are rooted, about midsummer. The shades and sash are removed in early October, and in late autumn, after most of their leaves have fallen, the rooted plants are taken out of the frames, so that these can be made ready for a new lot of cuttings very early the next spring. The stronger of the rooted plants taken out of the frames are set at once in their permanent places in the field plantation. Those less strongly rooted are placed in nursery beds at a spacing of about 10 inches each way, where they remain during the winter and the following growing season.

WINTER CUTTINGS.

The rooting of leafy cuttings of the blueberry in summer is very difficult, because in a temperature above 70° F. the cuttings blacken and die. With the aid of a shaded greenhouse, winter cuttings can be started early enough to make roots before warm weather comes on. Similar results can be secured in coldframes so located, sheltered, and manipulated as to prolong their low temperature as late as possible into the season.

The essentials of a successful coldframe for blueberry propagation are: (1) That it be located on the cool, shaded, north side of a building or in some other situation where it will not receive reflected heat from neighboring structures. (2) The frame must receive an abundance of light but no direct sunlight, a condition best secured in the case of isolated frames by the use of clean white muslin shades. Frames on the north side of a building will also require shade in early morning and late afternoon from March to September. On sunless days all shades should be removed, so that the cuttings will receive as much light as possible. (3) There should be ample space for the circulation of cool air between the frames and the shade. A shade at the height of about 7 feet from the

ground not only allows such circulation but makes it easy to work among the frames. (4) The frames should be kept closed until the cuttings are rooted. This closing not only keeps the air saturated with moisture and prevents the drying of the cuttings, but it also tends to maintain a cool ground temperature within the frame.

When frames are thus located, constructed, and managed, the maximum temperature on sunny days within the frames is often 10 degrees lower than the shade temperature outside, and the period of safety for cuttings that are not yet rooted is greatly prolonged. Low temperatures can be maintained in such coldframes much later in the season than in a greenhouse of the ordinary construction, even though the greenhouse is well shaded and well ventilated.

The use of a greenhouse in which to start the cuttings, followed by the transfer of the cutting boxes to coldframes at the beginning of warm weather, permits an even more prolonged protection of the cuttings than can be secured in either greenhouse or coldframe alone and increases the percentage of rooted plants.

The directions for rooting winter cuttings of the blueberry by the use of a coldframe are as follows:

1. Make the cuttings in late winter before the buds have begun to swell. If more convenient, they may be made in late autumn, after the leaves have fallen, laid rather loosely in clean moist sphagnum in a covered but ventilated box or other package, and stored until early spring on ice at a temperature just above freezing or in commercial cold storage at a temperature of about 35° F., if such storage is available.

2. Make the cuttings from wood of the preceding summer's growth, rejecting such portions as bear the large fat flowering buds. The cuttings are to be made from well-matured unbranched twigs or shoots grown in well-lighted situations, and therefore well stored with starch. Excellent wood for cuttings is afforded by the long stout shoots that grow the first summer from a blueberry plant that has been pruned to the stump. In the swamp blueberry these have few or no flowering buds and often are 3 to 5 feet in height and a quarter of an inch or more in diameter at the base.

3. About 4 to 5 inches is a suitable length for finished cuttings. A sharp thin-bladed knife should be used. In the finished cutting the upper end of the diagonal cut at the base of the cutting should come just below a sound bud, and the cut at the upper end of the cutting should be about an eighth of an inch above a sound bud. If the cuts are first made with pruning shears, remove with the knife the bruised wood at the cut ends. The diagonal knife cuts should be as short as is practicable without bruising the bark or splitting or straining the wood. Cuttings that have been kept in cold storage should be recut at both ends, so as to present clean surfaces that show no discoloration. In order to avoid infection of the cuttings, the knife must be kept clean. This may be done conveniently by dipping the blade in alcohol and wiping it on a clean towel. The cuttings must not be allowed to become dry. This is easily prevented by laying them in the fold of a clean moist towel.

4. The coldframe may be of the usual form, the top about 1 foot above the surface of the cutting bed at the front and 2 feet at the back, and tightly constructed of material not less than an inch in thickness, with closely fitting sash of the ordinary kind. The cutting bed, 4 inches in depth, should be laid down over a groundwork of gravel or other material that will provide good

drainage. On this groundwork place about 1 inch of clean chopped sphagnum moss and over the moss about 3 inches of pure clean sand. Moisten the sand with clean rain water or other pure water (free from lime) from a sprinkling pot.

5. After making deep slits at suitable intervals in the sand with some clean implement, set the cuttings in the slits at a spacing of about 2 to 3 inches each way according to size, the base of the cutting being in the sand a little above the sphagnum, and see that the sand is so closely and firmly packed about the base of the cutting that the cut surface is in contact with the sand, but be careful not to injure the delicate raw tissue at the base of the cutting by pushing forcibly into the sand. Smooth the surface of the bed by a final watering. Cover the frame closely with the sash, so that the air within will be moist.

6. Do not allow the temperature inside the frame to go above 65° F. Prolonged temperatures above 70° are likely to ruin the cuttings. Do not, on the other hand, allow the cutting bed or the cuttings to freeze.

7. Shade the frame with white muslin at a height of 2 to 7 feet above the frame, so as to keep the sunlight off the glass and at the same time to permit a sweep of air between the glass and the shade. The shade should be so arranged as to be removable on cloudy days or at any time when the frame is shaded by other objects.

8. Keep the air inside the box saturated or nearly saturated with moisture. This condition will be shown by the condensation of the moisture on the under side of the glass at night or at other cool portions of the day.

9. Watering should be as infrequent as practicable, only sufficient to keep the sand moist but well aerated and the atmosphere in the box saturated. If the sash fits tightly, the period between necessary waterings may extend over several weeks.

10. After the cuttings have callused at the base, the new twigs have pushed from the upper buds (Pl. VIII) and their growth has been terminated by the browning of the tips, and the new leaves have reached their full size and acquired the dark-green color of maturity, when the formation of roots is about to begin, the surface of the bed is to be mulched with about half an inch of a mixture of sifted peat, 2 parts, and clean sand, 1 part, carefully watered after application, so that some of the acid water from the peat will be carried down into the sand bed about the base of the cuttings. (See Pl. IX, fig. 1.)

11. When all or most of the cuttings in the frame have begun to root, ventilation of the frame should be begun. The best superficial evidence that a cutting has rooted is the development of secondary twig growth, either from the apex of one of the first set of new twigs or from another bud lower down on the old wood of the cutting. (See Pl. IX, fig. 2, and Pl. X.) If secondary growth does not take place, the development of a plump but dormant bud at the apex of one of the leafy twigs is also good evidence that the cutting has begun to root. Cuttings that are healthy but not yet rooted at the time ventilation begins usually die from excessive transpiration.

12. Ventilation should be only slight at first and should be increased very gradually, the transition to full ventilation extending over a period of several weeks. If any of the sensitive secondary growth begins to wilt, reduce the ventilation immediately until the wilting ceases. Be especially careful not to give too much ventilation on windy days.

13. All cuttings that are dying should be removed from the bed at once. Those injured by too high temperature usually turn brown at the base first, the dead area progressing upward until the new growth collapses. Those otherwise sound but suffering from excessive ventilation before they are rooted usually indicate their bad condition by the marginal yellowing of their leaves before they drop and the stems become withered.

14. The plants are best left in the open coldframe all winter, mulched with leaves, preferably oak leaves, and in the early spring, before the buds have begun to push, they should be very carefully lifted and moved, with the whole root mat and adhering soil intact, to a peat and sand nursery bed at a spacing of about a foot each way.

ROOT CUTTINGS.

The early experiments with root cuttings gave such a small percentage of rooted plants that further experiments in the greenhouse were abandoned. At Whitesbog, N. J., however, in order that the roots as well as the tops of selected wild plants might be utilized, cuttings of the roots were made about 3 to 4 inches long and of all sizes down to a little less than an eighth of an inch in diameter. These were given the same treatment as tubered cuttings in coldframes. A high percentage of rooted plants resulted. (See Pl. XI.) This may prove to be one of the most satisfactory methods of propagating plants that have large root systems.

TREATMENT OF YOUNG PLANTS.

When blueberry plants, either large or small, are grown in porous pots, the surface of the pot should never be allowed to become dry, for the rootlets which grow through the soil to the wall of the pot for air are extremely fine and easily killed by drying, to the great injury of the plant. This danger may be eliminated by bedding the pots to the rim in a well-drained bed of sand or by setting the pot in another pot of 2 to 4 inches greater diameter, with a packing of moist sphagnum moss between and broken crocks at the bottom. (See Pl. XII, fig. 1.)

A burning of the young leaves and growing tips of twigs is often produced by the hot sun from the middle of June to the middle of September. Plants in pots or nursery beds are easily protected from such injury and forced to their maximum growth by a half-shade covering of slats, the slats and the spaces between being of the same width. On cloudy days the shade should be removed. It should not be used in the fall or spring.

During the winter the rooted cuttings, or 1-year-old plants, should be kept outdoors, exposed to freezing temperatures, their soil mulched with leaves, preferably oak leaves. When kept in a warm greenhouse during the winter they make no growth before spring. Even then their growth is abnormal, often feeble, or sometimes deferred for a whole year.

FIELD PLANTING.

Plants from cuttings or rooted shoots are ready for permanent field planting when they are 1 or 2 years old and 6 to 18 inches high. (See Pl. XII, fig. 2.)

It is a curious fact that these plants send out no new roots in spring until they are in full leaf, when their flowering is nearly or

quite finished and their principal twig growth has ceased. It is important, therefore, in taking up either a wild or a cultivated plant from the open ground that as much as possible of the old root mat be carefully lifted with the plant, for upon this the plants depend for moisture until their new rootlets are formed.

In the case of mature wild bushes with very large root systems, when it is practicable to secure but a fraction of the root mat, say a disk only 3 or 4 feet in diameter, it is the best procedure to cut all the stems at the time of transplanting to stumps 1 to 2 inches high. The bush will then produce a new and symmetrical top of a size suited to the capacity of the roots. The wood that is removed may be used for cuttings if the plant is sufficiently valuable.

The stems that make up a bush usually develop fibrous roots on their basal portions beneath the surface of the soil and above the root crown, at which the several stems unite. Such plants can be divided into several when taken up for transplanting. As many as 30 plants, each cut to a stump and with its own small but sufficient portion of the root mat, have been secured in this way from a large wild plant. By utilizing the various methods of propagation described in this publication as many as 600 cuttings of roots, stems, and twigs have been made from a single very large wild bush.

In resetting plants from which the tops have been removed, the stumps should be made to project about an inch above the surface of the ground. New shoots are formed in spring from such exposed stumps much earlier than from stumps covered with soil and not receiving the warmth of the sun's direct rays. If the plant when reset is made to occupy a moderate depression in the ground, the old stump and the bases of the new stems can afterward be covered with soil and a new root system will finally develop from the new wood.

When blueberry plants are set out in early spring, before the buds have begun to push, they usually make excellent growth, and for all plants that are pruned to the stump early spring is the best season for transplanting.

Conditions with unpruned plants, however, are different. Since blueberry plants make no new root growth until late spring, it often happens that a period of hot days intervenes between planting and rooting, and many plants are injured by an excessive loss of water before they have had time to make connection with the water supply of the surrounding soil through the development of new roots. The danger of such injury is greatest in the case of plants transplanted from pots. The old root ball sends up most of its water to the leaves, and in consequence, being at first, as a rule, in imperfect capillary contact with the new outside soil, the root ball commonly contracts slightly. The contraction is often sufficient to put the roots at the surface of the root ball permanently out of contact with the surrounding soil, and the plant may continue to suffer severely from

drought, although the soil outside the root ball contains plenty of moisture.

An early autumn field planting has furnished a remarkably successful means of avoiding this trouble with potted plants. At this season the excessive heat of summer is over, the plants are in full and vigorous leaf, and, being taken from pots, carry their whole root system with them. The formation of new roots begins at once and proceeds with great activity until the leaves are shed, at the approach of winter. In the spring, when new leaf growth begins, the plants are already well rooted in the soil. They pass through the early hot period without injury and develop remarkable size and vigor by autumn.

In preparing for a field plantation one precaution of special importance must not be overlooked. For the production of a crop of fruit under field conditions, insects are required to carry pollen from one flower to another. The honeybee works little on blueberry flowers. Her tongue is so short that she can not easily reach the nectar. The flowers are pollinated chiefly by bumblebees, whose tongues are long, and by some of the solitary wild bees that are small enough to crawl through the narrow opening of the corolla. When blueberry flowers are pollinated with pollen from their own bush the berries are fewer, smaller, and later in maturing than when the pollen comes from another bush. Some bushes are almost completely sterile to their own pollen. (See Pl. XIII.) The pollen of a plant grown from a cutting is likewise unsatisfactory for the pollination of the parent plant or of other plants grown from cuttings of it. It is important, therefore, that a plantation should not be made up wholly from cuttings from one bush. Two stocks should be used, a row of plants from one stock being followed by a row from the other.

In the permanent field plantation the bushes should be set 8 feet apart each way. When they reach mature size they will nearly or quite cover the intervening spaces.

When blueberry culture is to be tried in a sandy or gravelly soil deficient in peat or peatlike matter, the plants should be set in separate holes or trenches about 12 inches deep in a mixture of two to four parts of peat or half-rotted oak leaves to one part of clean sand. The excavations should be wide enough to provide ample space for new growth of the roots, not less than a foot each way from the old root ball. In small plantings, if the materials for the mixture are easily available in quantity, an 8-inch bed of it may be laid down over the whole surface of the ground, and if a planting is to be tried on a soil wholly unsuited to the blueberry, the area may first be covered with a 6-inch layer of sand, the bed of peat and sand mixture being then laid down on top of the sand layer. Wherever used, the peat and sand mixture should be thoroughly manipulated, so as to

give it a uniform texture before the plants are set out in it, for in a soil in which layers of peat alternate with layers of sand the capillary connection of the two is usually imperfect, and a plant rooted in the peat may suffer severely from drought, although the neighboring sand still has water to spare. For a similar reason it is important that when the plant is first set out, the peat and sand mixture shall be very tightly pressed and packed about all sides of the old root ball.

To secure full vigor of growth the ground between the bushes must be kept free from all other vegetation. On rocky uplands or in situations deficient in peat a continuous mulch of oak leaves, when it is practicable to secure them, will help toward this end, as well as keep the soil in the necessary acid condition. It is more economical, however, to choose such a location for the plantation as will permit the use of horse-drawn machinery and will make mulching unnecessary.

The most favorable location for blueberry culture is a moist area with a peat covering and sand subsoil, the peat preferably of such a thickness that deep plowing will turn up some of the underlying sand.

The land should be so ditched that the water level can be kept at least a foot below the surface of the ground during the growing season.

The ground should be plowed to the depth of about 8 inches and repeatedly harrowed or otherwise tilled during the season preceding the planting, in order to kill the wild vegetation. The best time for such plowing is late spring, after the principal vegetation has used up its winter store of starch in completing its early growth and before the leaves have matured and the roots have begun the new storage of starch with which they can send up new sprouts.

The tillage of the plantation after the young bushes have been set out should be sufficiently thorough to keep down all competing vegetation. This is best done by horse cultivation, with careful hand hoeing and hand weeding close about the plants. As the bushes grow older and their roots extend into the spaces between the rows, they develop root mats close beneath the surface of the soil. The tillage over these root mats should be very shallow, not more than 2 or 3 inches. This is probably best accomplished by the use of a small, light spring-tooth cultivator with the teeth set closer together than usual.

In case of drought, the drainage ditches may be used to bring in water for subirrigation. But unless the surface of the ground is very level, subirrigation is likely to result in the injury of plants in the lower spots by excess of water. In uneven areas, therefore, surface irrigation, if accompanied by good drainage, is preferable to subirrigation and should be used if practicable.

Fertilizer experiments have shown that lime is positively injurious to blueberry plants and that stable manure, while producing a

temporary stimulation of vegetative growth, is likely to cause serious injury later. For those desiring to experiment with fertilizers the following acid mixture is recommended, applied at the rate of 1,000 pounds per acre, or one-fifth of a pound per square yard:

	Pounds.
Acid phosphate (high grade, about 16 per cent available phosphoric acid)	600
Sulphate of potash (50 per cent potash)	200
Sulphate of ammonia (20 per cent nitrogen)	200

(Muriate of potash may be substituted for sulphate of potash.)

This and similar acid mixtures have been used with success on blueberry plants in both pot and field experiments, with no evidence thus far of cumulative injurious effects. However, as no fertilizer is required to make the swamp blueberry fruit abundantly and continuously in suitable peat and sand soils properly handled, the use of fertilizers in commercial plantations is not at present advocated.

The swamp blueberry does not require a yearly pruning. When one of the stems of a bush becomes unproductive from injury or old age it should, of course, be cut out. If a large part of a bush needs removal it is better to cut all the stems to the ground and let the plant send up new shoots, all of the same age, to form a wholly new and symmetrical top.

YIELD AND PROFITS.

By proper manipulation in the greenhouse, seedling blueberry plants can often be made to ripen a few berries in less than a year, but they do not come into commercial bearing in field plantations until they are 3 to 4 years old (Pls. XIV, XV, XVI), when the plants are 1 to 3 feet high. They then increase slowly to full size and full bearing. Wild bushes of the swamp blueberry live to great age, often 50 to 100 years, still bearing heavily, and they often attain a height of 6 to 8 feet when growing in full sunlight; still more when shaded. Individual stems may remain productive for 10 to 25 years. When dead they are replaced by new and vigorous shoots from the root.

The field plantings resulting from the recent experiments in blueberry culture are too young to show the mature yield. Fortunately however, there is, near Elkhart, Ind., a small blueberry planting of mature age. The returns from this plantation set forward our knowledge of yields by at least a decade. The plantation is about 2½ acres in extent. It was started in 1889 in a natural blueberry bog, which was first drained and then set with unselected wild-blueberry bushes. The plantation was profitable from the first, but exact records of yield and receipts are available only for the years 1910 to 1915, when the plantation was 21 to 26 years old. The data are shown in Table I.

TABLE I.—*Yield and receipts from a plantation of blueberries near Elkhart, Ind., 1910 to 1915, inclusive.*

Year.	Yield per acre.	Price (approximate average per quart).	Receipts per acre.	Profits per acre.
	Quarts.	*Cents.*		
1910 (a year of "almost total failure" because of late spring freezes)	419	17⅛	$71.87	$10
1911	2,266	12⅞	292.44	139
1912	2,379	12⅝	305.75	147
1913	1,770	15⅛	267.64	139
1914 (a year of severe midsummer drought)	1,397	14½	201.94	92
1915	2,214	14½	321.00	170
Average for the 6 years	1,741	14½	243.44	116

The annual expenses for weeding, cultivation, and irrigation were about $20 per acre. The cost of picking was 5 cents a quart. The general cost of maintenance of the equipment was about $2 per acre per year, the crates and boxes being used repeatedly. The computation includes an estimated annual charge of $12 per acre for interest, $2 for taxes, and $4 for depreciation or sinking fund.

It must be borne in mind that these figures are based on the yields from wild bushes transplanted without selection as to individual productiveness or the size of the berries. With bushes propagated from selected varieties, the yield should be greater and the berries much larger, this greater size probably effecting a reduction in the cost of picking and certainly an increase in the selling price.

Only a beginning has been made in the improvement of the blueberry. In a series of experiments involving the selection of superior wild strains, the growing of hybrids, and the forcing of choice varieties to quick fruiting by budding them on strong seedling stocks, berries seven-eighths of an inch in diameter have already been produced in the greenhouse. The yield and profits from such bushes in field plantations are not yet known. (For an illustration of a cluster of very large berries, see Pl. XVII.)

CONCLUSION.

The introduction of the blueberry into agriculture has a much more profound significance than the mere addition of one more agricultural industry to those already in existence. Blueberries thrive best in soils so acid as to be considered worthless for ordinary agricultural purposes. Blueberry culture, therefore, not only promises to add to the general welfare through the utilization of land almost valueless otherwise, but it offers a profitable industry to individual landowners in districts in which general agricultural conditions are especially hard and unpromising, and it suggests the possibility of the further utilization of such lands by means of other crops adapted to acid conditions.[1]

[1] For a discussion of the principles of acid-soil agriculture in districts in which the cost of lime is prohibitory, consult "The Agricultural Utilization of Acid Lands by Means of Acid-Tolerant Crops," United States Department of Agriculture, Bulletin No. 6, 1913.

BLUEBERRY PLANTS SHOWING THE EFFECT OF ACID SOIL AS CONTRASTED WITH RICH GARDEN SOIL.

The three large 1-year-old blueberry plants were grown in a greenhouse in a peat soil. All three are over 24 inches high, the one at the left 27 inches. Standing on the middle pot is a small glass pot containing a seedling of the same age and origin as the others but potted in a rich garden soil. The difference in results shows the fundamental importance of a peaty acid soil for blueberry culture. (One-eighth natural size.)

NEW SHOOTS ON A STUMPED BLUEBERRY PLANT.

The three shoots shown grew after the plant had been cut to the stump. Their white color at the base indicates the depth of the propagating bed through which they forced their way and from which the plant was taken to be photographed. Roots had already begun to develop. (Natural size.)

BLUEBERRY PLANT FROM A ROOTED STUMP SHOOT.

The old cut-off stem shown in the illustration is the rooted base of a vigorous shoot from a stumped blueberry. It was removed from the parent plant a year after stumping, was potted in a 4-inch pot, and when photographed was in process of developing two new leafy branches. (Natural size.)

FIG. 1.—TUBERED BLUEBERRY CUTTING WITH YOUNG SPROUTS DEVELOPING.

FIG. 2.—TUBERED BLUEBERRY CUTTING WITH SPROUTS ROOTING AT THE BASE.

The sprout at the left in figure 1 had emerged from the sand and begun to develop green leaves above the surface. The sprout near the center of figure 1 is younger, the whole of it still in the rootstock stage. The two sprouts in figure 2 are developing roots on their lower parts, above the dying wood of the old cutting and beneath the surface of the cutting bed. (Both natural size.)

WELL-ROOTED SPROUTS FROM A TUBERED BLUEBERRY CUTTING.

Sprouts with roots thus far developed are ready for potting, even though secondary growth, as in this case, has not yet taken place. These two sprouts are so closely united that they can not safely be separated into two plants. (Natural size.)

NEWLY POTTED BLUEBERRY PLANT FROM A TUBERED CUTTING.

After the sprout from the tubered cutting had rooted and before it was potted it had made secondary growth from the tip of the original sprout. (Natural size.)

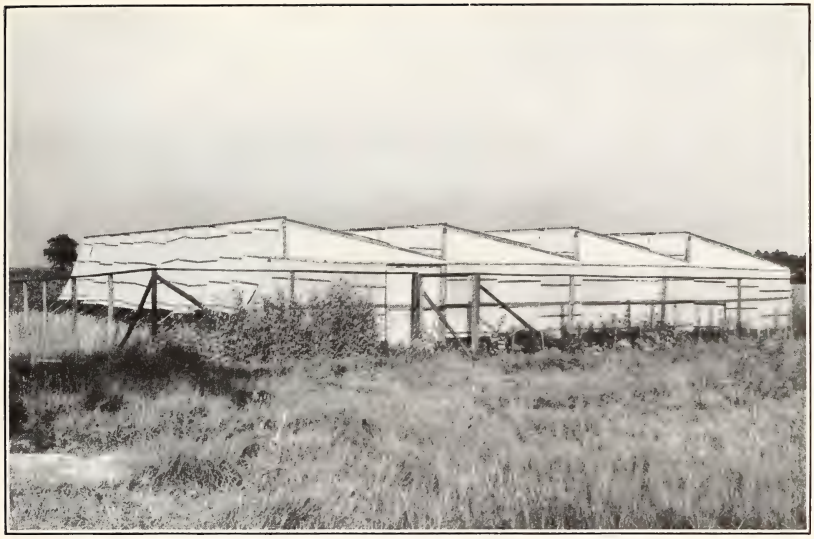


FIG. 1.—BLUEBERRY PROPAGATION SHELTER AT WHITESBOG, N. J.

The illustration shows the north and west sides of the shelter and the fence surrounding it. The shelter covers four rows of frames, which face south. Each of the four sections is 9 feet high and 10 feet 10 inches from front to back.

FIG. 2.—BLUEBERRY PROPAGATION FRAMES AT WHITESBOG, N. J.

Each sash is of the standard size, 3 feet wide and 6 feet long. The wooden sides of the cold-frames rise 2 feet from the ground at the back and 1 foot at the front. The lowest part of the roof joists is 6½ feet above the ground.

BLUEBERRY CUTTINGS IN EARLY STAGES OF GROWTH.

The figure at the left shows a cutting callused at the base and the uppermost bud pushing, but the green bracts and young leaves not yet expanded. In the middle and right-hand figures callusing has proceeded farther at the cut surfaces, both top and bottom, and the formation of new leafy twigs is well under way; but the growth of the tips has not yet been terminated. As shown in the right-hand figure, twigs are often produced from two of the upper buds, sometimes more. (Natural size.)

FIG. 1.—BOX OF BLUEBERRY CUTTINGS AFTER MULCHING.

The box is 10 by 12 inches by 8 inches deep, inside measurement. The new twigs have completed their primary growth, their leaves have reached full size, and the formation of roots is about to begin. Secondary twig growth has not yet taken place.

FIG. 2.—BOX OF BLUEBERRY CUTTINGS SHOWING SECONDARY GROWTH.

Most of the cuttings have put out and matured their strong secondary twigs. This condition of twig growth is conclusive evidence that the cuttings are well rooted and that the box is ready for ventilation.

WELL-ROOTED BLUEBERRY CUTTING.

This cutting with the sand adhering to it has just been removed from its cutting bed. The illustration shows the secondary twig growth that took place from the apex of the primary twig after the cutting had begun to form roots. The dark-colored bud scales just below the middle of the leaf-bearing axis mark the apex of the primary growth and the base of the secondary growth. This cutting was in the cutting bed from February 3 to August 6, when the photograph was taken. Under greenhouse propagation the cutting is ready for potting; under outdoor propagation it should remain in the cutting bed until late autumn or early spring. (Natural size.)

BLUEBERRY PLANTS FROM ROOT CUTTINGS.

The illustration, from a photograph taken on July 27, shows the excellent growth secured from root cuttings buried in a coldframe cutting bed early in the spring of the same year. This section of the coldframe is of the size of a standard sash, 3 feet in width and 6 feet from front to back.

FIG. 1.—DOUBLE-POTTED BLUEBERRY PLANT.

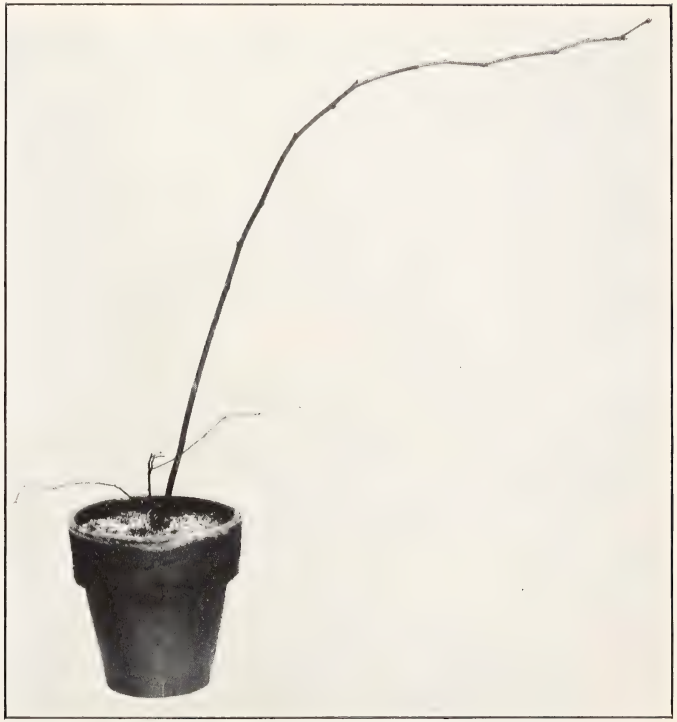


FIG. 2.—TWO-YEAR-OLD BLUEBERRY PLANT FROM A WINTER CUTTING.

The plant shown in figure 1 is in a 4-inch pot, which is set in an outer 7-inch pot with a packing of moist sphagnum moss between. Rooted sprouts from tubered cuttings which were potted in this manner developed in their second year an average stem length of 25 inches. The illustration is from a photograph of one of these plants. (About one-eighth natural size.) The photograph from which figure 2 was made was taken on November 14, after the plant had shed its leaves. Plants of this size and vigor are ready for the field plantation. (One-fourth natural size.)

EFFECT OF SELF-POLLINATION IN THE BLUEBERRY AS COMPARED WITH CROSS-POLLINATION.

These two twigs, both natural size, were in equally good situations on the same bush, contained the same number of flowers, all pollinated by hand at the same time with equal care, and the fruits were photographed on the same day. The only difference in treatment was that the pollen used on the left-hand twig came from other flowers on the same bush, while the pollen for the right-hand twig was taken from another bush. The cross-pollinated flowers produced a full cluster of handsome fruit. The self-pollinated flowers produced no ripe fruit, all the fruit that set remaining small and green and later dropping off, until at the time the photograph was taken only two such imperfect fruits remained. A plantation made up wholly from cuttings from a single bush would produce little or no fruit. At least two original propagation stocks are necessary.

CLUSTER OF BLUEBERRIES ON A 3-YEAR-OLD HYBRID.

This cluster of berries, which is of natural size, is from one of the hybrid bushes shown in Plate XV. The berries had a very light blue color, firm but juicy flesh, exceptionally delicious flavor, and seeds so small as not to be noticeable when the berries were eaten. The largest berry on this bush was 15 millimeters in diameter. Other bushes in the plantation bore berries 17 millimeters in diameter, larger than those of either parent. The small berries on the cluster were still green. Such berries increase rapidly in size during the few days of ripening.

FIG. 1.—THREE-YEAR-OLD BLUEBERRY PLANT IN COMMERCIAL BEARING.

This plant is a hybrid between two selected wild stocks, from Greenfield, N. H., and Brown Mills, N. J. They were hybridized in the greenhouses at Washington in the summer of 1912, and the hybrid seeds were sown September 9. The young plants were carried over winter in the greenhouse, and early in September, 1913, they were sent to Whitesbog, N. J., and set out in a trial field plantation. The photograph was taken July 27, 1915, when the plant was a little less than 3 years old. The plant is one of those shown in figure 2 (below). (About one-fifth natural size.)

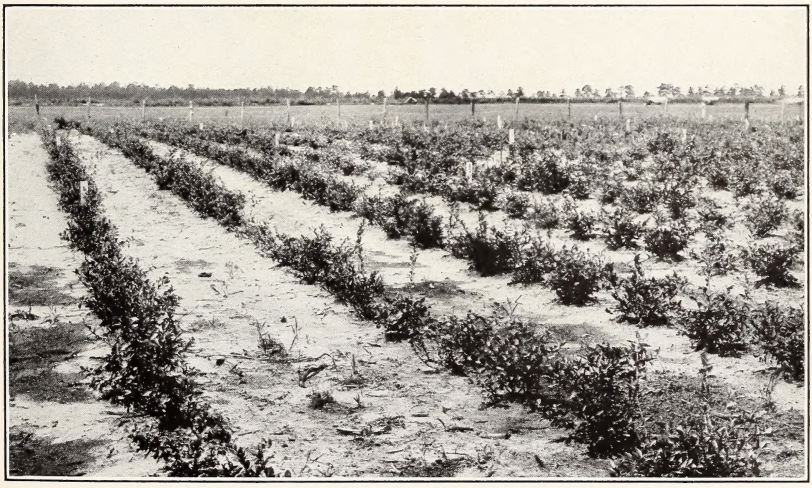
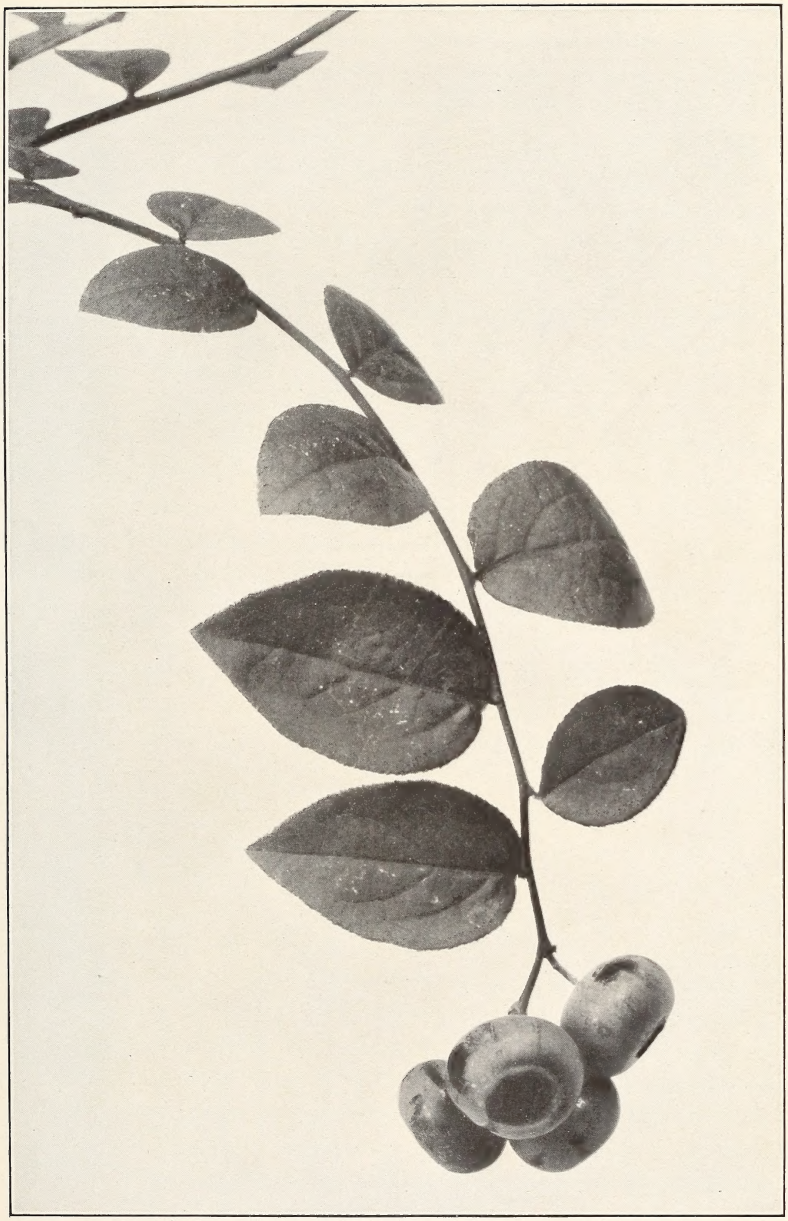


FIG. 2.—PLANTATION OF 3-YEAR-OLD BLUEBERRY HYBRIDS AT WHITESBOG N. J.

These hybrids are of the same age and parentage and have received the same treatment as the plant shown in figure 1 (above). In the third year from the seed they produced their first commercial crop, valued at $37 per acre, gross receipts. The rows are 5 feet apart and the plants 3 feet apart in the row, too close a spacing for a permanent plantation (which should be 8 by 8 feet) but correspondingly more productive in the earlier years.

FOUR-YEAR-OLD BLUEBERRY HYBRID.

This is one of a series of hybrids made in 1911 between selected wild plants of a low-bush blueberry (*Vaccinium angustifolium*) and a high-bush or swamp blueberry (*V. corymbosum*), both from Greenfield, N. H. The plants are now in the trial plantation at Whitesbog, N. J. They fruit much earlier in the year than the wild New Jersey swamp blueberry. The photograph was taken July 7, 1915. Some of the berries were ready to pick two weeks before that time. These 4-year-old hybrids yielded more than three times as large a crop as the 3-year-old hybrids shown in Plate XV. The best 4-year-old bush bore 2 quarts of berries. (About one-sixth natural size.)



HYBRID BLUEBERRIES OF LARGE SIZE.

These berries, shown in their natural size, reached a diameter of 18.6 millimeters, nearly three-quarters of an inch. They were produced in the greenhouses at Washington on a plant 12 months old, in a 4-inch pot. One of the parents of this hybrid was itself a selected hybrid, of selected high-bush and low-bush New Hampshire parentage, and the other parent was a selected wild swamp blueberry from New Jersey. It is not yet known what results these hybrids will yield in field plantations. Many thousand hybrids will be fruited in the trial plantation at Whitesbog in the pine barrens of New Jersey, and from these a few of the best bushes will be selected for final propagation and distribution.